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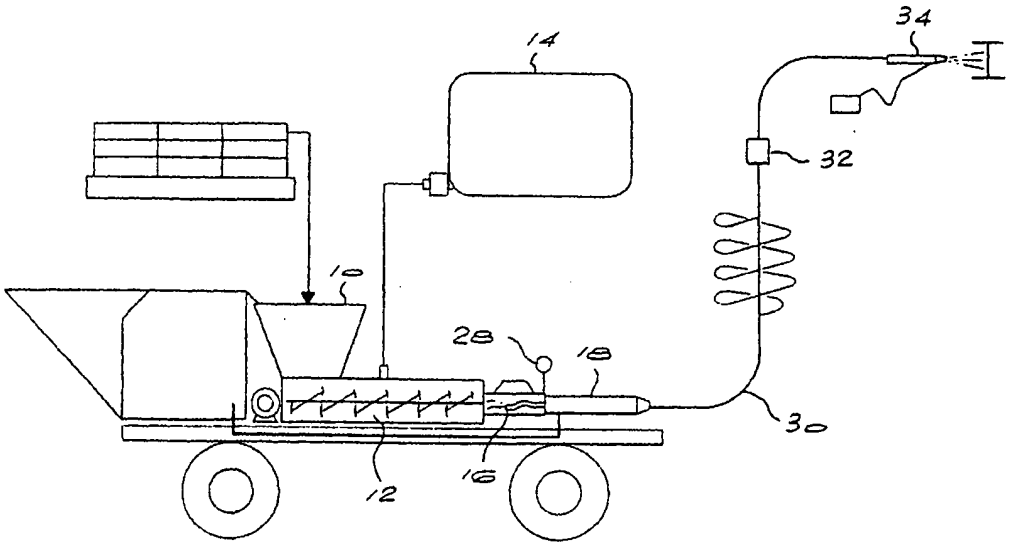
(54) Title: METHOD FOR THE PRODUCTION OF A HYDRAULIC BINDER FOAM



(57) Abstract: A method for the production of a hydraulic binder foam which may subsequently be used to make a finished product such as a thermal insulation product, includes the steps of preparing a paste or a slurry from a hydraulic binder and a foaming agent; feeding the paste or the slurry to a foam generator and introducing compressed air into the foam generator to produce an aerated product; and pumping the aerated product and additional compressed air from the foam generator through a length of piping thus causing turbulence of the aerated product and the compressed air so as to produce a hydraulic binder foam exiting the length of piping. The hydraulic binder foam exiting the length of piping is air saturated and thus of a consistent density as a function of the liquid to hydraulic binder ratio rather than as a function of the method of production.

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METHOD FOR THE PRODUCTION OF A HYDRAULIC BINDER FOAM

BACKGROUND TO THE INVENTION

THIS invention relates to a method for the continuous production of a hydraulic binder foam.

It is well known to produce a hydraulic binder foam by introducing an aqueous foam into a paste or a slurry of the hydraulic binder in water. The aqueous foam may be produced in a foam generator by passing a stream of water containing a foaming agent such as a surfactant, a protein or a hydrophilic polymer, through a pipe and injecting air into the passing solution stream to generate a stable aqueous foam.

For example, PCT/GB 98/03556 to Windsor Technologies Limited teaches a method of making a composite product by mixing (i) a hydraulic binder; (ii) finely divided lignocellulosic fibres; and (iii) water optionally containing a polyvinyl alcohol, the water being present in an amount sufficient to form a paste; introducing a foam generated from a polyvinyl alcohol into the paste and

mixing to form a foamed product; forming the foamed product into a desired shape; and allowing the hydraulic binder to set to form the composite product.

The composite product may be, for example, a building board or the like.

Another example of the manufacture of a product from a hydraulic binder foam is disclosed in United States Patent No 4,518,652 to United States Gypsum Company.

There is, however, always a need for another method of producing a hydraulic binder foam.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided a method for the production of a hydraulic binder foam including the steps of:

(a) mixing:

(i) a hydraulic binder; and

either

(ii) a foaming agent;

or

(iii) a foam formed from a foaming agent and water; and

(iv) water;

to form a paste or a slurry having a solid component and a liquid component;

(b) feeding the paste or the slurry to a foam generator and introducing compressed air into the foam generator to produce an aerated product;

(c) pumping the aerated product and additional compressed air from the foam generator through a length of piping thus causing turbulence of the

aerated product and the compressed air so as to produce a hydraulic binder foam exiting the length of piping.

In step (a) there may be included in the paste or the slurry a retarder for the setting of the hydraulic binder.

In step (c), the length and configuration of the length of piping, the proportion of compressed air to the paste or the slurry, and the pressures of the compressed air and of the paste or the slurry, are used to control the final hydraulic binder foam density.

In step (c), as the foam exits, there may be added an accelerator for the setting of the hydraulic binder.

According to a second aspect of the invention there is provided a method of making a finished product from a hydraulic binder foam produced as described above, including the steps of:

(d) dispensing the hydraulic binder foam onto a surface, e.g a surface to be protected or decorated, or a surface of a mould or a surface of a moving belt; and

(e) allowing the hydraulic binder to set to form the finished product.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of apparatus for use in a method of the invention; and

Figure 2 is a schematic view of a foam generator for use in the method of the invention.

DESCRIPTION OF EMBODIMENTS

The crux of the invention is a method for the production of a hydraulic binder foam by feeding a paste or a slurry of a hydraulic binder, either a foaming agent or a foam formed from a foaming agent and water, and water, to a foam generator, and introducing compressed air into the foam generator to produce an aerated product, and then pumping the aerated product and additional compressed air from the foam generator through a length of piping thus causing turbulence of the aerated product and the compressed air so as to produce a hydraulic binder foam exiting the length of piping.

The hydraulic binder foam exiting the length of piping is air saturated and thus of a consistent density as a function of the liquid to hydraulic binder ratio rather than as a function of the method of production. This contrasts with conventional methods where, for the same liquid to hydraulic binder ratio, differences in equipment or methods used lead to differences in the density of the hydraulic binder foam.

The method may be operated on a continuous basis.

In step (a) of the method of the invention, there is prepared a paste or a slurry from a hydraulic binder, either a foaming agent or a foam formed from a foaming agent and water, and water.

Thus there may be added to the hydraulic binder a foaming agent and water, for subsequent generation of a foam, or a foam may be pre-generated from a foaming agent and water, and this foam may then be added to the hydraulic binder, together with additional water.

By "hydraulic binder" is meant an inorganic binder which in the presence of water hydrates and sets. The hydraulic binder may be selected from the group

consisting of a hydraulic cement including Portland cement, a calcium sulphoaluminate cement, a high alumina cement, a gypsum cement, calcium sulphate hemi-hydrate in either the alpha or beta form, magnesium oxychloride, magnesium oxysulphate, a pozzolanic binder such as finely ground blast furnace slag or fly ash, silica fume, or a mixture of two or more thereof.

In addition to the hydraulic binder which must be in finely divided dry powder form, (i.e having a particle size of 475 m^2/kg or smaller) there may also be added to the paste or the slurry a filler in dry particle or fibre form.

The filler may comprise dry inorganic particles or fibres such as for example silica (which is preferably present when the hydraulic binder contains a Portland cement and a product formed therefrom is subjected to autoclave curing), diatomaceous earth, expanded perlite, exfoliated vermiculite, a refractory filler such as alumina or grog or colloidal silica, ceramic fibres, mineral fibres and glass fibres.

The filler may also comprise dry natural organic particles or fibres such as paper fibres, e.g common mixed paper waste, paper mill sludge, pulp, cellulose and the like, or agricultural fibres such as fibres extracted from wattle bark, palm fibre, kenaf, and reeds, and natural organic particles such as ground cork, and sawdust.

The filler may also comprise dry synthetic particles or fibres such as organic particles derived from milled thermoplastic foams, e.g polyvinyl chloride and expanded polystyrene foams; milled thermosetting foams, for example phenol formaldehyde resole resin foams, urea formaldehyde foams and polyurethane rigid or flexible foams; and organic fibres such as carbon, aramid, polyacrylonitrile, polyvinyl alcohol, polyethylene, polypropylene, polyester and acrylics.

The purpose of adding one or more fillers is as follows:

(i) to contribute syntactic voids in the hydraulic binder foam as a function of the low bulk density of the filler. Examples of suitable fillers in this regard are exfoliated vermiculite, expanded perlite, ground phenol formaldehyde resole resin foam, polystyrene foam re-grind, cork, flexible or rigid polyurethane re-grind, and ground urea formaldehyde foam.

(ii) to propagate improved properties of the hydraulic binder foam. Examples of suitable fillers here are silica flour in Portland cement, where the product is subsequently to be autoclaved, alumina in a calcium aluminate cement to improve the refractory nature of the product, and exfoliated vermiculite in a high alumina cement to improve the refractory nature of the product.

(iii) when the filler is a fibre, then the fibres reinforce the product and may also propagate improved sound attenuation or noise reduction co-efficience of the final product, and may promote thixotropy of spray applied hydraulic binder foams.

(iv) to enhance foam stability by air bubble entrapment, in which case a suitable filler is a cellulose fibre, particularly paper mill sludge or common mixed paper waste, or other water absorbent fibre.

When the bulk density of the filler is similar to the bulk density of the hydraulic binder (which is approximately 700 kg/m^3) then the amount of filler used may be up to an equivalent amount by mass of the hydraulic binder. However, as the bulk density of the filler decreases, the amount by mass of the filler which may be used, relative to the hydraulic binder, decreases proportionately.

The foaming agent may be any suitable foaming agent and is preferably selected from the group consisting of:

1 a surfactant;

2 a protein compound; and

3 a hydrophilic compound or polymer which is soluble, miscible or dispersible in water.

When a surfactant is used as the foaming agent, it may be used in an amount of from 0,005% to 0,5% inclusive by mass of the combined mass of the liquid component and the surfactant in the paste or slurry.

Suitable surfactants include the fluoro surfactants produced by duPont, such as Zonyl FS300, which is a general purpose non-ionic fluoro surfactant which is free of organic solvents, unaffected by hard water or pH, with a large capacity to wet out and which is a highly effective foamer.

When a protein compound is used as the foaming agent, it may be used in an amount of from 2% to 5% inclusive by mass of the combined mass of the liquid component and the protein compound in the paste or slurry.

Suitable protein compounds are the hydrolysed protein based concentrates.

When a hydrophilic compound or polymer is used as the foaming agent, it may be used in an amount of from 1% to 10% inclusive by mass of the combined mass of the liquid component and the hydrophilic compound or polymer in the paste or slurry.

Examples of suitable hydrophilic polymers are modified starches, natural carbohydrates such as gums or seaweed colloids, semi-synthetic polymers such as the cellulose ethers, hydrogels such as the homo- and co-polymer derivatives of acylic and methacrylic acid, or the polyacrylamide polyacrylate co-polymers, and dispersions such as polyvinyl acetate and styrenated acrylics.

The preferred hydrophilic polymer is polyvinyl alcohol which may be used in an amount of from 1% to 10% inclusive by mass of the combined mass of the liquid component and the polyvinyl alcohol in the paste or slurry, or preferably in an amount of from 3% to 8% inclusive by mass of the combined mass of the liquid component and the polyvinyl alcohol in the paste or slurry. The volume increase of the foamed paste or slurry over the unfoamed paste or slurry is strongly influenced by the viscosity of the polyvinyl alcohol used. Those preferred are the partially hydrolysed grades with a degree of hydrolysis mol % in the range of 82% to 90%, preferably about 87%, a viscosity in the range of from 9 mPa.s to 65 mPa.s inclusive for a 5% solution concentration in water at 20°C, with an ester value mg KOH/g of 140, and residual acetyl content weight percent of 10,7. Examples of suitable polyvinyl alcohols are the Mowiol grades by Clariant, 4/88 through to 40/88, which, at 20°C and at a 5% concentration in water, have viscosities of 12 mPa.s for 8/88, (which is most preferred for use with Portland cement) and 55 mPa.s for 18/88 (which is most preferred for use with gypsum).

In certain circumstances it may be advisable to use a combination of foaming agents, such as for example a hydrophilic polymer such as polyvinyl alcohol, together with a protein compound such as gelatin or a modified cellulose.

The proportion by mass of the liquid component in the paste or slurry to the hydraulic binder in the paste or slurry is preferably in the range of from 2:1 to 1:1.3 inclusive. It is the proportion of the liquid component in the paste or slurry to the hydraulic binder in the paste or slurry which determines the final density of the hydraulic binder foam exiting the length of piping.

In step (a) there may be added into the paste or the slurry a retarder for the setting of the hydraulic binder. For example, when the foaming agent is polyvinyl alcohol, and the hydraulic binder is calcium sulphate hemi-hydrate, a suitable retarder is the compound Retardan P, used in an amount of about

0.1% inclusive by mass of the hydraulic binder. Another example of a suitable retarder is a sodium polyacrylate and polyacrylic acid blend, such as Good-rite K-752 by B F Goodrich, used at similar concentrations.

In step (a) there may also be added into the paste or the slurry other additives such as a hydrophobic agent, a synergistic binder, or a coupling agent.

In step (a), the hydraulic binder, the foaming agent or the pre-generated foam, and the water are preferably blended and mixed continuously.

In step (b), the paste or the slurry is fed, preferably by means of pumping, to a foam generator. Suitable pumps include a piston pump, a diaphragm pump, a rotor stator pump, or a worm type impeller, capable of resisting gaseous back pressure and cavitation, in other words which is of a positive displacement design.

Further in step (b), compressed air is introduced into the foam generator and thus into the paste or the slurry to produce an aerated product.

The foam generator is preferably cylindrical, the cylinder preferably having no obstructions. The compressed air is preferably added into the foam generator through one or preferably several air ports, the pressure of the compressed air being greater than the static pressure of the slurry or the paste.

The air volume is preferably syncronised to the slurry or paste pumping speed in order to control the density and air assisted conveyance of the aerated product into the length of piping in step (c).

In step (c), the aerated product and additional compressed air are pumped from the foam generator through a length of piping, thus causing turbulence of

the aerated product and the compressed air so as to produce a hydraulic binder foam exiting the length of piping.

The length of piping may have any suitable configuration, and may preferably be coiled to ensure inversion and air saturation of the products, and must be of a sufficient length to allow for the turbulent conveyance of the aerated product in the presence of the compressed air to form the foam.

The pressure of the paste or the slurry fed into the foam generator is typically of from 1 to 3 bar inclusive. The pressure of the compressed air introduced into the foam generator is preferably of from 3 to 8 bar inclusive at ground level, but may be increased up to 20 bar inclusive for conveyance of the aerated product from the foam generator through the length of piping.

The length of piping may have any suitable length, for example a length of from 10 meters to 30 meters where the length of piping is coiled, and of up to 75 meters when the length of piping is straight. The diameter of the piping may be any suitable diameter, for example up to 25 mm.

The additional compressed air in step (c) is used to convey the product along the length of piping with minimal build up of static pressure in the system, and to mix the air and the slurry or the paste by turbulence, breaking up the air bubbles to the minimum possible size in the paste or the slurry, to produce a satisfactory foam.

The excess air in the length of the piping may be released or removed at any point.

There exits the length of the piping a hydraulic binder foam which is air saturated and thus of a consistent density.

To this may be added an accelerator. For example, when the hydraulic binder is calcium sulphate hemi-hydrate, suitable accelerators are hydrated gypsum, potassium sulphate, aluminium sulphate, and certain other sulphate compounds. When the hydraulic binder is a Portland cement, suitable accelerators are alkali silicates such as sodium silicate. Where the hydraulic binder is a calcium aluminate, a suitable accelerator is lithium carbonate.

According to the second aspect of the invention, the hydraulic binder foam so produced may be formed into a finished product by dispensing the hydraulic binder foam onto a surface, e.g a surface to be protected or decorated, or the surface of a mould, or the surface of a moving belt, and the hydraulic binder may be allowed to set to form the finished product.

The dispensing of the hydraulic binder foam may be by means of pouring or spraying or any other suitable method.

The method of the invention will now be described in more detail with reference to the accompanying drawings.

Referring to Figure 1, a hydraulic binder, and any other dry components such as particles or fibres are intimately blended in a blender 10. The blended dry components are then fed from the blender 10 into a mixer 12, into which is added a solution of water and a foaming agent from a tank 14. There is produced a paste or a slurry which is then fed by means of a worm pump 16 into a foam generator 18.

The foam generator 18 is schematically illustrated in Figure 2. It comprises air inlets 20 which feed into a plenum chamber 22 and then through air injection ports 24 into a central cylindrical section 26 where the compressed air is mixed with the paste or the slurry.

The static pressure in the system may be measured by means of a slurry pressure gauge 28.

The aerated product exiting the foam generator 18 is pumped turbulently with additional compressed air through a length of piping 30. Excess air is optionally allowed to escape through an escape valve 32. The hydraulic binder foam so produced is dispensed, optionally with air assistance, via a nozzle 34. Alternatively, the hydraulic binder foam may be dispensed onto a suitable surface such as a conveyor to produce slabs, boards or shapes.

After the hydraulic binder in the foam has set, which may be accelerated by the addition of accelerators or the like, the product is dried or cured, and if necessary post treated.

Utilising the method of the invention, there may be produced, for example, a gypsum foam which may be pumped onto surfaces such as steel to protect steel girders and structural components against fire. For this purpose, it is often necessary to pump the foam across large distances, and in this case, the foam must be retarded to accommodate delays, break-downs and normal working shifts. The foam must then be accelerated at or near its point of dispensation so as to allow the hydraulic binder to set.

Examples

Example 1

In an example of the invention, a slurry was formed from a gypsum cement (650g), a solution of water and a hydrophilic polymer foaming agent (800g), and a retarder, Retardan P (0,1% by weight of the gypsum cement). After formation of the paste or the slurry, this was pumped to a foam generator, into which was injected compressed air, and the aerated product so formed was then pumped through a length of piping of varying lengths. The results of these tests are illustrated in Table 1.

Table 1

	Test					
	1	2	3	4	5	6
Pipe Length (m)	21	21	21	42	68	68
Height (m) (above the ground)	0	0	0	0	0	8,6
Pipe Diameter (mm)	20	20	20	20	20	20
Air lines (off)	1	2	3	3	3	3
Density Before (kg/m^3)	0,75	0,75	0,75	0,75	0,75	0,75
Density After (kg/m^3)	0,287	0,202	0,19	0,214	0,206	0,206
Pressure (Bar) (in the length of piping)	3,9	4,8	5,2	5,8	6,2	6,2

Example 2

A further test was conducted where the gypsum foam was repumped through a foam generator. The results of this test are set out in Table 2 and illustrate the stability of the foam.

Table 2

	Test 1
Pipe Length (m)	21
Height (m)	0
Pipe Diameter (mm)	20
Density Before (kg/m^3)	0,213
Density After (kg/m^3)	0,157

By "Density Before" there is meant the density of the product exiting the foam generator and by "Density After" there is meant the density of the hydraulic binder foam after its passage through the length of piping at its point of delivery.

Example 3

A foam was pre-generated from a 5% solution of polyvinyl alcohol-Mowiol 18/88 in water, foamed to a density of 90 g/ℓ. There was also prepared a gypsum slurry comprising 800 units by mass of gypsum and 500 units by mass of a 1% solution of polyvinyl alcohol – Mowiol 18/88 in water. The water for

forming the slurry included the Mowiol 18/88 to compatibilize the surface tensions of the slurry and the pre-generated foam.

The pre-generated foam and the gypsum slurry were mixed in a proportion of 1 000 units by mass of the pre-generated foam to 1 300 units by mass of the gypsum slurry, to produce an aerated product in a foam generator. This aerated product and additional compressed air was then pumped from the foam generator through a length of piping thus causing turbulence of the aerated product and the compressed air to produce a hydraulic binder foam exiting the length of piping with a final dry density of 110 kg/m^3. This foam was of application as a thermal insulation.

CLAIMS

1 A method for the production of a hydraulic binder foam including the steps of:

(a) mixing:

(i) a hydraulic binder; and

either

(ii) a foaming agent;

or

(iii) a foam formed from a foaming agent and water; and

(iv) water;

to form a paste or a slurry having a solid component and a liquid component;

(b) feeding the paste or the or the slurry to a foam generator and introducing compressed air into the foam generator to produce an aerated product;

(c) pumping the aerated product and additional compressed air from the foam generator through a length of piping thus causing turbulence of the aerated product and the compressed air so as to produce a hydraulic binder foam exiting the length of piping.

2 A method according to claim 1 wherein the hydraulic binder foam exiting the length of piping is air saturated.

3 A method according to claim 1 or claim 2 wherein the hydraulic binder is selected from the group consisting of a hydraulic cement, a calcium sulphoaluminate cement, a high alumina cement, a gypsum cement, calcium sulphate hemi-hydrate in either the alpha or beta form, magnesium oxychloride, magnesium oxysulphate, a pozzolanic binder, or a mixture of two or more thereof.

4 A method according to any one of claims 1 to 3 wherein the foaming agent comprises a surfactant used in an amount of from 0,005% to 0,5% inclusive by mass of the combined mass of the liquid component and the surfactant in the paste or the slurry.

5 A method according to any one of claims 1 to 3 wherein the foaming agent comprises a protein compound used in an amount of from 2% to 5% inclusive by mass of the combined mass of the liquid component and the protein compound in the paste or the slurry.

6 A method according to any one of claims 1 to 3 wherein the foaming agent comprises a hydrophilic compound or polymer used in an amount of from 1% to 10% inclusive by mass of the combined mass of the liquid component and the hydrophilic compound or polymer in the paste or the slurry.

7 A method according to claim 6 wherein the foaming agent is a polyvinyl alcohol with a degree of hydrolysis mol/% in the range of from 82 to 90 inclusive and a viscosity in the range of from 9 mPa.s to 65 mPa.s inclusive for a 5% solution concentration in water at 20°C.

8 A method according to any one of claims 1 to 7 wherein the proportion by mass of the liquid component to the hydraulic binder in the paste or the slurry is from 2:1 to 1:1.3.

9 A method according to any one of claims 1 to 8 wherein the pressure of the paste or the slurry fed into the foam generator is from 1 bar to 3 bar inclusive.

10 A method according to any one of claims 1 to 9 wherein the length of piping is coiled.

11 A method according to any one of claims 1 to 10 wherein the pressure of the compressed air in the length of piping causing the turbulence of the aerated product and the compressed air so as to produce the hydraulic binder foam is from 3 bar to 8 bar inclusive.

12 A method according to any one of claims 1 to 11 wherein in step (a) there is included in the paste or the slurry a retarder for the setting of the hydraulic binder.

13 A method according to any one of claims 1 to 12 wherein in step (c) as the hydraulic binder foam exits the length of piping there is added an accelerator for the setting of the hydraulic binder.

14 A method of making a finished product from a hydraulic binder foam including the steps of:

(a) mixing:

(i) a hydraulic binder; and

either

(ii) a foaming agent;

or

(iii) a foam formed from a foaming agent and water; and

(iv) water;

to form a paste or a slurry having a solid component and a liquid component;

(b) feeding the paste or the or the slurry to a foam generator and introducing compressed air into the foam generator to produce an aerated product;

(c) pumping the aerated product and additional compressed air from the foam generator through a length of piping thus causing turbulence of the aerated product and the compressed air so as to produce the hydraulic binder foam exiting the length of piping;

(d) dispensing the hydraulic binder foam onto a surface; and

(e) allowing the hydraulic binder to set to form the finished product.

15 A method according to claim 14 wherein the hydraulic binder foam exiting the length of piping is air saturated.

16 A method according to claim 14 or claim 15 wherein the hydraulic binder is selected from the group consisting of a hydraulic cement, a calcium sulphoaluminate cement, a high alumina cement, a gypsum cement, calcium sulphate hemi-hydrate in either the alpha or beta form, magnesium oxychloride, magnesium oxysulphate, a pozzolanic binder, or a mixture of two or more thereof.

17 A method according to any one of claims 14 to 16 wherein the foaming agent comprises a surfactant used in an amount of from 0,005% to 0,5% inclusive by mass of the combined mass of the liquid component and the surfactant in the paste or the slurry.

18 A method according to any one of claims 14 to 16 wherein the foaming agent comprises a protein compound used in an amount of from 2% to 5% inclusive by mass of the combined mass of the liquid component and the protein compound in the paste or the slurry.

19 A method according to any one of claims 14 to 16 wherein the foaming agent comprises a hydrophilic compound or polymer used in an amount of from 1% to 10% inclusive by mass of the combined mass of the liquid component and the hydrophilic compound or polymer in the paste or the slurry.

20 A method according to claim 19 wherein the foaming agent is a polyvinyl alcohol with a degree of hydrolysis mol/% in the range of from 82 to 90

inclusive and a viscosity in the range of from 9 mPa.s to 65 mPa.s inclusive for a 5% solution concentration in water at 20°C.

21 A method according to any one of claims 14 to 20 wherein the proportion by mass of the liquid component to the hydraulic binder in the paste or the slurry is from 2:1 to 1:1.3.

22 A method according to any one of claims 14 to 21 wherein the pressure of the paste or the slurry fed into the foam generator is from 1 bar to 3 bar inclusive.

23 A method according to any one of claims 14 to 22 wherein the length of piping is coiled.

24 A method according to any one of claims 14 to 23 wherein the pressure of the compressed air in the length of piping causing the turbulence of the aerated product and the compressed air so as to produce the hydraulic binder foam is from 3 bar to 8 bar inclusive.

25 A method according to any one of claims 14 to 24 wherein in step (a) there is included in the paste or the slurry a retarder for the setting of the hydraulic binder.

26 A method according to any one of claims 14 to 25 wherein in step (c) as the hydraulic binder foam exits the length of piping there is added an accelerator for the setting of the hydraulic binder.

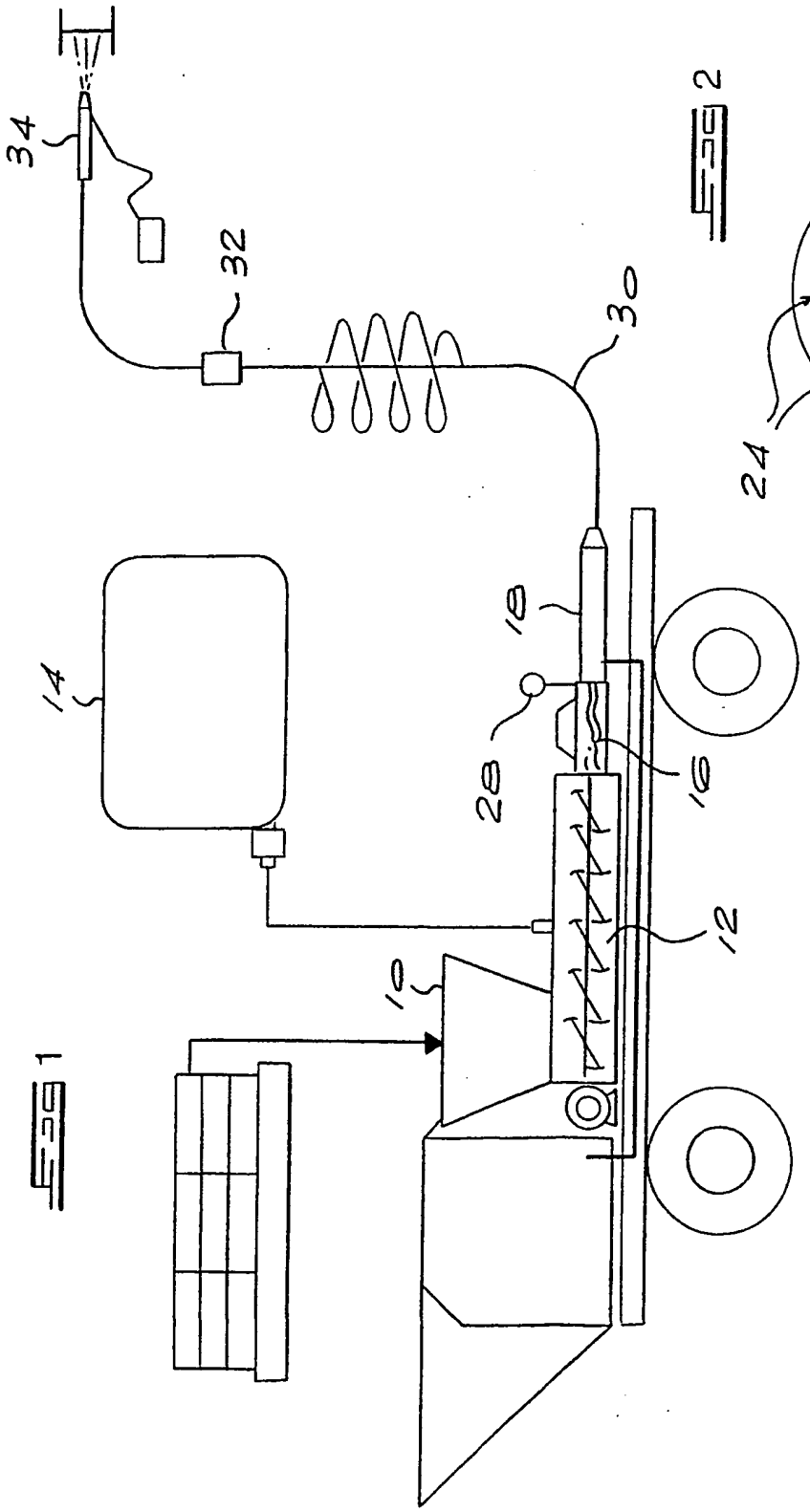

Fig 1

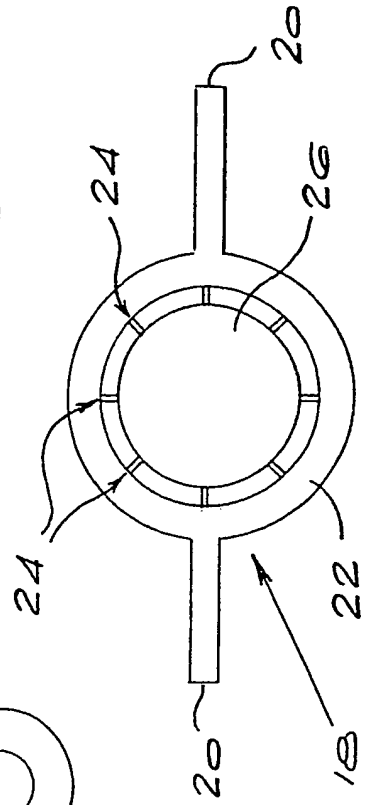

Fig 2